Description

Method for synchronizing a radio communication system divided into radio cells

The invention relates to a method for synchronizing a radio communication system divided into radio cells according to the preamble of claim 1.

Cellular radio communication systems, in particular mobile radio systems, are divided into synchronized and non-synchronized radio communication systems.

In the former, base stations of adjacent radio cells are mutually synchronized in terms of time and/or frequency. For synchronizing, in particular for time synchronizing, GPS receivers are employed for instance on the part of the base stations, or base stations are synchronized with each other by means of synchronizing signals requiring to be exchanged at high cost. Since, moreover, radio transmission resources are occupied during the transmission of synchronizing signals, said resources will no longer be available for transmitting chargeable useful subscriber data (payload).

In non-synchronized radio communication systems, base stations of adjacent radio cells are not synchronized with each other.

As a representative instance of a mobile radio system, FIG 3 shows a cellular radio communication system according to the prior art.

Three adjacent radio cells FZ1 to FZ3 each have an assigned base station BTS01 to BTS03. Each of said base stations BTS01 to BTS03 provisions a number of the mobile stations T01 to

TO12 assigned to the respective radio cell FZ1 to FZ3, with a total of four carrier frequencies f9 to f12 being assigned by means of a "frequency reuse" planning method to a first base station BTS01 of a first radio cell FZ1, a total of four carrier frequencies f1 to f4 being assigned thereby to a second base station BTS02 of a second radio cell FZ2, and a total of four carrier frequencies f5 to f8 being assigned thereby to a third base station BTS03 of a third radio cell FZ3 exclusively for data transmission.

In a connection direction referred to as the "downlink" DL from the base station to the mobile station, each of the carrier frequencies f1 to f12 has seven timeslots TS1 to TS7 as radio transmission resources, while in a connection direction referred to as the "uplink" UL from the mobile station to the base station each of the carrier frequencies f1 to f12 has five timeslots TS1 to TS5 as radio transmission resources. Free, unused timeslots are shown by way of example for the carrier frequencies f2, f7, and f11 and designated by the letter "F".

The use of what are termed "orthogonal frequency division multiplexing" ("OFDM" for short) transmission technologies is gaining increasing significance in particular for mobile radio networks of cellular design because new services such as, for instance, transmitting video at fast data rates can be transmitted cost-efficiently with the aid of said technologies.

In radio communication systems, in particular in an OFDM radio communication system, the necessary multiple use of carrier frequencies in adjacent radio cells gives rise to what is termed "co-channel interference", which can be reduced with the aid of what is termed a "frequency reuse" planning method.

FIG 4 shows, referred to FIG 3, a synchronizing situation of the radio cells FZ1 to FZ3 that corresponds to the prior art.

It is assumed below that the system is a time-synchronized radio communication system whose adjacent radio cells FZ1 to FZ3 have a "frequency reuse" factor of one, which is to say the radio cells FZ1 to FZ3 employ the same carrier frequencies.

Each base station BTS01 to BTS03 and the mobile stations T01 to T012 assigned to each base station BTS01 to BTS03 have in each case a base-station-specific carrier frequency deviation Delta01 to Delta03 which deviates from a predefined value MIT and is plotted vertically. Said carrier frequency deviation Delta01 to Delta03 is due in each of the individual base stations BTS01 to BTS03 to electrical components of the respective base station, for example to base-station-specific local oscillators.

In particular when OFDM radio transmission technologies are used in a synchronous radio communication system, the fast data rates employed necessitate extremely accurate synchronizing which, however, can only be implemented at very high cost.

The object of the present invention is to disclose a low-cost synchronizing method for a cellular radio transmission system, in particular for an OFDM radio communication system.

Said object of the invention is achieved by means of the features of claim 1. Advantageous developments are cited in the subclaims.

The method according to the invention enables synchronizing in terms of time and/or frequency to be implemented in a cellular radio communication system by simple means.

Said synchronizing especially advantageously enables in particular adjacent base stations to employ radio transmission resources from a stock that is commonly assigned to the base stations for data transmission. Particularly efficient radio resource management is facilitated thereby. Dynamic use of available radio transmission resources in the individual radio cells is introduced or, as the case may be, realized.

Available radio transmission resources are in each case optimally assigned in keeping with the momentary traffic load, with unevenly distributed subscriber occupancies being particularly advantageously evened out.

Radio transmission resources are in a preferred embodiment allocated taking account of an interference situation in a radio transmission resource requiring to be selected. This will enable, for example, two adjacent base stations each individually radio provisioning a mobile station assigned to it simultaneously to employ a timeslot of a carrier frequency as the radio transmission resource for radio provisioning said mobile stations, provided the interference situation in the selected timeslot will allow this.

Synchronizing will facilitate the application on the part of the base station and/or mobile station of interference suppression methods that are optimized in particular for mutually synchronous payload and interference signals.

The inventive method for synchronizing dispenses with transmitting additional signaling information for

synchronizing that has hitherto had to be exchanged between the base station and mobile station in a higher protocol layer. Synchronizing according to the invention is in each case implemented automatically and solely through signal processing and subsequent adjusting of a synchronizing condition of the base stations or, as the case may be, mobile stations, which operations are performed on the receive side.

With the aid of the method according to the invention it is possible in the case of, say, large organized events in a simple manner to add further base stations at a later time, or, as the case may be, undertake a change associated therewith in the number of radio cells. By means of evaluating signals of already active mobile stations, a base station added later will synchronize itself with base stations already in operation. The added base station will dynamically select radio transmission resources needed for operation in such a way that co-channel interference on adjacent radio cells or, as the case may be, the mobile stations assigned to the radio cells will in each case be minimized.

The method according to the invention is used particularly advantageously in an OFDM radio communication system employed especially preferably for services having fast data rates.

The invention is explained in more detail below with the aid of a drawing:

FIG 1 shows an OFDM radio communication system having
        synchronizing according to the invention,
FIG 2 shows inventive synchronizing performed on the part of a
        base station shown in FIG 1,
FIG 3 shows the cellular radio communication system according
        to the prior art described as a representative instance

in the introduction to the description, and

FIG 4 shows the synchronizing situation described in the
introduction to the description and corresponding to the
prior art.

As a representative instance of a mobile radio system, FIG 1
shows an OFDM radio communication system having synchronizing
according to the invention.

Three adjacent radio cells FZ1 to FZ3 each have an assigned
base station BTS1 to BTS3. Each of the base stations BTS1 to
BTS3 individually provisions a number of mobile stations T11
to T33 assigned to the respective radio cell FZ1 to FZ3, with
a total of four mobile stations T11 to T14 being assigned to a
first base station BTS1 for radio provisioning while a total
of five mobile stations T21 to T25 are allocated to a second
base station BTS2 for radio provisioning. A total of three
mobile stations T31 to T33 are allocated to a third base
station BTS3 for radio provisioning.

For transmitting subscriber data, all three base stations BTS1
to BTS3 employ radio transmission resources that are commonly
assigned on equal terms and are established by a total of
twelve carrier frequencies f1 to f12. Each of the carrier
frequencies f1 to f12 has in a connection direction referred
to as the "downlink" DL from the base station to the mobile
station seven timeslots TS1 to TS7 as radio transmission
resources, while each of the carrier frequencies f1 to f12 has
in a connection direction referred to as the "uplink" UL from
the mobile station to the base station five timeslots TS1 to
TS5 as radio transmission resources. Free, unused timeslots,
shown by way of example for the carrier frequencies f2, f8,
and f12 are designated by the letter "F".

Compared with FIG 3, through synchronizing according to the
invention the exclusive allocation of carrier frequencies f1
to f12 to base stations or, as the case may be, radio cells
has here been rescinded.

Synchronizing according to the invention is explained in more
detail below with the aid of the first radio cell FZ1 as a
representative instance of the second and third radio cell FZ2
and FZ3, with the term "synchronizing" here to be understood
as both time synchronizing of the timeslots of the carrier
frequencies and frequency synchronizing of the carrier
frequencies.

Alongside signals of the mobile stations T11 to T14 assigned
to it, the first base station BTS1 of the first radio cell FZ1
also receives signals from mobile stations of the adjacent
radio cells FZ2 and FZ3 on the uplink UL. Said receiving takes
place automatically with no additional monitoring of other
frequency bands.

For example, the first base station BTS1 also receives signals
of the mobile stations T21 and T22 of the second radio cell
FZ2 and signals of the mobile stations T31 and T32 of the
third radio cell FZ3 on the uplink. The first base station
BTS1 determines a first time deviation and a first frequency
deviation based on the received mobile station signals of the
adjacent radio cells FZ2 and FZ3 and from these values derives
a   suitable   time-synchronizing   value   and   a   frequency-
synchronizing value with which the first base station BTS1
finally synchronizes itself.

Viewed as representative of all the mobile stations, alongside
signals of the base station BTS1 of its own radio cell FZ1 a
third mobile station T13 of the first radio cell FZ1 also

receives signals of the adjacent base stations BTS2 and BTS3 of the radio cells FZ2 and FZ3 on a downlink DL. The third mobile station T13 then determines a second time deviation and a second frequency deviation based on the received base station signals and from these values derives a suitable time-synchronizing value and a frequency-synchronizing value with which the mobile station T13 finally synchronizes itself.

Said synchronizing according to the invention is repeated, for example, frame-by-frame, which, time-averaged, will produce precise, self-organizing time and frequency synchronizing.

Through synchronizing according to the invention, interference suppression methods are now employed in an advantageous embodiment thereof on the part of the base stations and/or mobile stations.

Through synchronizing according to the invention, particularly flexibly and adaptively implemented radio resource management is especially advantageously realized since all the base stations are able to access a common stock of radio transmission resources, with, for example, carrier frequencies being selected taking account of minimal co-channel interference. Transmission resources are allocated to mobile stations exclusively by the base station respectively assigned to the respective mobile station.

The rescinded exclusive allocating of carrier frequencies to base stations or, as the case may be, radio cells enables, for example, the base station BTS1 and the base station BTS3 to simultaneously use the timeslot TS5 of the carrier frequency f5 for radio provisioning respectively the mobile station T14 and the mobile station T32 if the interference situation in the timeslot TS5 will allow this. Said interference situation

is influenced by, for example, sectorized receiving and/or
transmitting antennas on the base stations or by propagation
characteristics of the radio signals or by the spatial
distance between the subscribers, etc.

With sectorizing, a base station for transmitting and/or
receiving radio signals has, for example, three antenna
arrangements each of which individually radio provisions a
sector with a beam angle of $120°$. A spatial separation or, as
the case may be, differentiation between radio signals is
achieved thereby and, depending on the choice of the sector's
beam angle, an improvement in an interference situation
accomplished.

In the event of inhomogeneous radio cell utilization, each of
the three base stations can, if required, access transmission
resources of the carrier frequencies either entirely or only
partially, as a result of which bottlenecks in the individual
radio cells are avoided when there is simultaneously
prevailing overcapacity in individual radio cells.

Newly added base stations synchronize themselves in
respectively relevant frequency bands and evaluate the
received signals accordingly for the purpose of time
synchronizing and carrier frequency synchronizing. A
subsequent expansion of the radio communication system or, as
the case may be, subsequent capacity increase can thus be
implemented at not very great cost.

Synchronizing according to the invention takes place
automatically and requires neither expensive signaling nor
expensive GPS synchronizing.

FIG 2 shows, referred to FIG 1, synchronizing performed on the

part of the base station BTS1.

A mobile-station-specific carrier frequency deviation is plotted vertically for each individual mobile station. The first base station BTS1 under consideration receives on the uplink UL signals sent by the mobile stations T21, T22, T12, T13, T11, T31, and T32 and from said signals determines a synchronizing value d1, represented here by way of example as a mean value by a hatched rectangle. The base station BTS1 corrects its synchronizing accordingly in the direction of the positive synchronizing value d1. The same applies analogously to the further base stations BTS2 and BTS3.

While not described here in further detail, synchronizing of the respective mobile stations takes place in a manner comparable to the above.

If a TDMA/FDMA multiple access method is employed in the above-mentioned cellular radio communication network, either one on its own or both in combination, and if what is termed a time-division duplex (TDD) mode is considered for transmission, then a signal r(t) received at the base station will consist of an overlaying of a plurality of signals of all the radio cells' mobile stations transmitting simultaneously employing the FDMA multiple access method.

From the received signal r(t), each base station determines the mean receive instant of overlaid OFDM symbols of the mobile stations located in the adjacent radio cells.

With the aid of correlating adjacent sampled values arranged having an OFDM symbol length N spacing, the result for a sampled value k is a metric $\lambda(k)$ whose values also have periodic values in the case of an FDMA uplink having the OFDM

symbol length N. The following applies:

$$\lambda(k) = \sum_{m=0}^{M-1} r(k+m)\, r^*(k+m+N)$$

where M stands for a window length across which metric values
are averaged for noise reduction purposes. Said length is as a
rule identical to that of what is termed a "guard interval". A
different length of a spacing N is in certain circumstances
chosen from correlated values and the window length M for
improving detection properties.

At the position of the mean time deviation of the signal
components of the mobile stations at a respective base
station, the absolute value of the metric $|\lambda(k)|$ assumes a
value that is proportional to the total power of the signals
of the mobile stations received from this cell. For this
reason the maximum absolute value of the metric $|\lambda(k)|$ is
sought after the metric values have been calculated and the
position of the maximum absolute value continues being used a
an estimation for the respective base station's time offset.
The metric values will be complex if a residual carrier
frequency deviation remains, which is why an approximation of
the mean carrier frequency deviation of the signals received
in the OFDM symbol can be determined from the phase measured
in the metric maximum for small values of the carrier
frequency deviation.

To separate the FDMA signals of different mobile stations, the
received signal is advantageously evaluated in the frequency
range as these are assigned to different subcarriers. The
respective carrier frequency deviation will in this case arise
from a phase rotation in the OFDM symbols received on each
subcarrier.

The frequency deviation of a partial carrier frequency $\delta f(k)$ is herein the result of the phase change in the transmission factors $H(n,k)$ of a partial carrier frequency k between two consecutive OFDM symbols having a time index n and $n+1$ with a temporal spacing T_s. The following thus applies:

$$\delta f(k) = \frac{1}{2\pi} \angle \left\{ \frac{H(n+1, k)}{H(n, k)} \right\} \frac{1}{T_s}$$

From the values of the adjacent radio cells' carrier frequency deviation that are obtained after estimating in the frequency range, a for example mean carrier frequency deviation of the mobile stations received from the adjacent radio cells is determined following an evaluation in accordance with the quality of the estimation.

The respective time deviation will be determined from the phase rotation between the subcarriers of a received OFDM symbol by a mobile station assigned to the same base station. From the values of the time deviation that are obtained after estimating in the frequency range, a for example mean time deviation of the mobile stations received from the adjacent radio cells is determined following an evaluation in accordance with the quality of the estimation.

Each base station will, with the aid of the determined time deviation and carrier frequency deviation, adjust its respective own carrier frequency and own transmitting instant in keeping with the determined values. Given a suitably designed control loop filter, this operation will automatically result in a convergent estimation.

Inventive synchronizing of a newly added base station in a TDD

radio communication system requires the following steps:

- uplink and downlink monitoring to determine a TDD frame
  structure,

- determining the absolute transmitting instant of all
  measured receiving instants, and

- evaluating the signals according to the above-cited scheme.

In each uplink phase, each base station determines useful
components of the mobile stations active in the radio cell and
the co-channel interference components originating from the
adjacent radio cells for each subcarrier.

Based on this information, each base station makes an
independent decision about a bandwidth to be occupied. The
subcarriers having a minimum interference component are
selected, with the base station making an adaptive decision,
as a function of an achievable channel quality, about the
position and number of subcarriers to be occupied and of the
physical transmission parameters to be used to be able to
optimally provision the mobile stations located within the
radio cell. Organization across different cells is not
required.

This type of multiple access avoids interference within a
radio cell and between mobile stations of adjacent radio
cells. Self-organizing optimizing of a multiple access method
employed is performed across different radio cells. This is
done taking account of the radio transmission channel
properties and of the momentary interference situation in a
cellular environment.